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AUTHOR	Keranto, Tapio
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ABSTRACT

Three factors associated with arithmetical processes (sequence skills, arithmetical strategies, and information processing capacity) were measured in individual interviews with 35 first-grade pupils, aged 7.6 to 8.6, in one Finnish school. Mathematics achievement was determined from information supplied by teachers. Attitudes were assessed twice, with a 3-day interval, for 67 first and second graders. The findings are presented with discussion. Counting skills showed extremely significant development during the year. Pupils made an extremely significant transfer from the use of external aids to the use of mental strategies, but evidence was found to support the view that external aids are significant and indispensible in the learning and teaching of mathematics. The development of information processing capacity was also extremely significant. Sequence skills and arithmetical strategies accounted for 52% to 59% of the variance on the various components of mathematics achievement. Interrelationships of skills were found. Attitude measures were more valid as age and academic ability increased. A lengthy list of references is included with this English summary. (MNS)

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Tapio Keranto Ass.Prof.,Dr University of Tampere
Department of Teacher Training in HML
Erottajakatu 12
13130 HML 13
Finland

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ARITMEETTISET PROSESSIT JA STRATEGIAT: YHTEYDET MATEMATIIKAN OPINTOMENESTYKSEEN, OPISKELUMOTIVAATIOON JA ASENTEISIIN

ENGLISH SUMMARY

Arithmetical Processes and Strategies: Their Relationship with Study Achievement, Motivation and Attitudes

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ENGLISH SUMMARY

Arithmetical Processes and Strategies: Their Relationship with Study Achievement, Motivation and Attitudes.

The study investigated the interrelationships between the following areas of mathematics education:

A. Sequence skills
B. Arithmetical Strategies
C. Information processing capacity in numerical contexts
D. Study achievement in mathematics in the first school year
E. Motivation for and attitudes towards mathematics study

The questions the experimental part of the study set out to examine were as follows:

1. To what extent and in what way do sequence skills, arithmetical strategies and information processing capacity develop during the first school year?
2. To what extent and in what way do sequence skills, arithmetical strategies and information processing capacity relate to study achievement in mathematics?
3. To what extent and in what way do attitudes towards mathematics learning relate to first-graders' arithmetical processes and achievement in mathematics?

With regard to arithmetical processes, this was a follow-up study the theoretical considerations and experimental results of which were closely linked to earlier studies by the author (Keranto 1981, 1983) and research in other countries (Carpenter et al 1981, 1982, Case 1972, 1974, 1980, Davidov & Andronov 1979, DeCorte et al 1982, Fuson 1981, Fuson & Hall 1982, Fuson et al 1982, Galperin 1957, Gelman & Gallistel 1978, Ginsburg 1977, Pascual-Leone 1970, Piaget 1952). The theoretical and experimental investigations of motivation and attitudes in mathematics study were for their part linked to previous research into attitudes (Malinen 1969, Leino 1977, Karjalainen 1982), cognitive psychology (Madsen 1966), work and performance motivation (Atkinson 1964, Chung 1977, McClelland et al 1953, Ruohotie 1982a, 1982b), individual orientation in study situations and phenomenological studies (Aebli 1967, Salonen et al 1982, Schutz 1970a, 1970b). The experimental investigation

of attitudes to mathematics study sought further to throw light on the role played by cognitive and affective factors in mathematics achievement.

Method. The factors associated with arithmetical processes (sequence skills, arithmetical strategies and information processing capacity) were measured in individual interviews in May 1983. All first-graders in one school (N=35) took part in the measurement, their ages ranging between 7.6 and 8.6. The standardised interview for one pupil lasted 35-45 min. depending on the pupil's arithmetical abilities, sequence skills and information processing capacity. The tests were conducted throughout by the author. The processes and strategies used by each child were recorded in a written code. Attitudes were measured by means of a straightforward multiple choice technique involving three alternatives (disagree-can't say-agree). The same measure was administered to the pupils twice, with an interval of three days intervening, in May 1983. In this way it was hoped to establish the reability and validity of each attitude-measuring item and the consistency of pupils' responses. All first and second-graders (N=35+32=67) took part in the measurement. Each measurement session took approximately one lesson (=45 min). The responses of the second-graders were used in assessing reliability and establishing attitudinal dimensions. This made the number of observations large enough for factor analyses to be carried out.

Measurement. The types of tasks used in the measurement are outlined below, with the abbreviations used and the number of items involved given in parentheses. The majority of items relating to arithmetical processes were identical with those used in the measurements carried out in autumn 1982 (Keranto 1983).

Sequence skills: "count" up from x by "N" (UPBY/6); "count" down from y by "N" (DOBY/6); "count" up from x by the same number m (SABY/5) (cf. Fuson & Hall 1982, Keranto 1983).

Arithmetical strategies of the types: Join minus (JOIM/2); Reversible (RJOIM/2); Combine minus (COBM/6) (cf. Carpenter et al 1982, Keranto 1983).

Information processing capacity: Enumeration Span when all numbers the subject must count up to (from 1) are given in advance (ESP(S)/13) (cf. Backward Digit Span (BDS), Case 1972, 1974, Keranto 1983).

Mathematics achievement: mental arithmetic in the range 0-20, written addition skill, written subtraction skill (MENTAL1, PLUS1, MIN1); mental arithmetic, written addition skill, written subtraction skill in the range 20-100 (MENTAL2, PLUS2, MIN2); verbal task solving skill (SOLV). The above were measured on a five-point scale (weak, passable, satisfactory, good, very good) and determined on information supplied specifically for this study by the firstgraders' teachers.

Attitudes towards mathematics study: difficulty experienced in mathematics learning (DIFF/3); necessity (NECES/3); willingness to try (TRY/6); experience of success (ESUC/3); cognitive and functional needs (KOGN/4 and FUNC/4); social needs (SOC/4); fear (FEAR/3); aggressiveness (AGGR/2); desire to have more/fewer hours (DESIR/2); (un)attractiveness of mathematics as compared with other subjects in the basic curriculum (ATTR).

Scoring: For the sequence skills UPBY and DOBY the scoring was based on the performance process as follows: 0 where no adequate strategy; 1 where the strategy involves external aids or number substitution; 2 where the strategy is either "calculate in advance which number is to be counted up to" or "keep a count of each number spoken". As for the SABY task, the scoring system was: 0 for failure to list the two following numbers; 1 where the listing of the intervening numbers helps; 2 for a direct, fluent response without listing the intervening numbers.

In the case of the arithmetical tasks JOIM, RJOIM and COBM the scoring was again based on strategies as follows: 0 where no

adequate strategy; 1 where there is a resort to external aids, fingers, blocks or other visual representation; 2 for a protracted mental calculation; 3 for performance based on factual knowledge.

Sum variables relating to the above tasks were formed as follows:

$$UPBY=\sum_{i=1}^{6}UPBYi,\quad DOBY=\sum_{i=1}^{6}DOBYi,\quad SABY=\sum_{i=1}^{5}SABYi,\quad \underline{JOIM}=\sum_{i=1}^{2}JOIMi+\sum_{i=1}^{2}RJOIMi,$$

$$COBM=\sum_{i=1}^{6}COBMi,\quad SEQU=UPBY+DOBY+SABY,\quad ARITME=\underline{JOIM}+COBM.$$

This formulation was supported by correlation and reability studies.

In the case of information processing capacity two variables were formed. The ESP variable recorded the number of success (N) fully completed tasks on the ESP(S) test ($N\leq 13$). The SPAN variable values were determined as follows: 0 or 1 where the pupil fails to reach the next level (no cases); 2 for more than half right on tasks involving the retention of two units of information (5 items); 3 for fulfilment of the previous criterion and more than half right on tasks involving three units of information (5 items); 4 for fulfilment of the previous criterion and over half right on tasks involving four units of information (3 items). In the case of every subject the criterion in question was fully satisfied.

The mathematics achievement five-point variables MENTAL1-2, PLUS1-2, MIN1-2 and SOLV were formed into the following sum variables: MENTAL=MENTAL1+MENTAL2; PLUS=PLUS1+PLUS2; MIN=MIN1+MIN2;CSKILL1=MENTAL1+PLUS1+MIN1; CSKILL2=MENTAL2+PLUS2+MIN2; CSKILL=CSKILL1+CSKILL2+SOLV. School grades at the end of the spring term yielded information on the pupils' general performance in mathematics (MAT), reading (READ), writing (WRITE) and manual skills (MANUAL). A three-point scale was used: 0 needing help; 1 fair; 2 good. Grades were also given for school behaviour, specifically good behaviour (BEH), conscientiousness (CONSC) and attention to detail (ATTEN) with the three-point

scale here: 0 unsatisfactory; 1 satisfactory overall; 2 regularly good. From these three-point variables were formed the following sum variables: LANGU=READ+WRITE; SUCCESS=MAT+LANGU+MANUAL and BEHAV=BEH+CONSL+ATTEN.

Attitude sum variables were also formed on the basis of correlation and factor analyses and reliability studies of the individual attitude variables: EMOTIO=AGGR1+AGGR2; TRY=TRY1+TRY2; DIFF=DIFF1+DIFF2+DIFF3; ESUC=ESUC1+ESUC2+ESUC3; FEAR=FEAR1+FEAR2 and KOGN=FUNC1+KOGN1+FUNC3+KOGN3. The responses on each attitude test item were scored on the three-point scale: 0 disagree; 1 can't say; 2 agree.

Results

Findings with regard to question 1: Binomial tests revealed an extremely significant ($p < .001$) development of UPBY and DOBY skills during the first school year. The vast majority of those children (73-100% depending on the task) who had been unable to perform such tasks on starting school were able to do them by spring using finger-counting or mental strategies. Again, those who on starting school had used finger-counting had most of them (67-100% depending on the task) gone over to the mental strategy "calculate in advance which number is to be counted up to". The consistency of memory strategies over the whole UPBY-DOBY field was high at 83%. Reliability figures for the sequence skills UPBY, DOBY and SABY were also high (.77-.91). As in earlier studies, the development of arithmetical strategies was investigated in connection with the Join minus, RJoin minus and Combine minus task types. Binomial tests revealed an extremely significant transfer from the use of external aids to the use of more developed mental strategies. In fact of those pupils using external aids or protracted mental strategies in the autumn term the majority (72-87% depending on the task) had switched by spring to applying factual knowledge. In the case of the Combine minus-type tasks, this meant that the pupils in question had applied the number distributions they had learned in school in determining an unknown number. Of those pupils who were unable to do Combine minus tasks in the autumn, most (50-65% depending on the task)

employed finger-counting strategies and some had achieved the level of factual knowledge. The extent to which resort was made to external aids increased as the size of the unknown and/or the known numbers increased. These findings strongly support the view that external aids are significant and indispensible in the learning and teaching of basic mathematics skills (cf. Keranto 1979, 1981, 1983). The consistency of the Combine minus task type was found to be high (80-94% depending on the number range), where as the consistency for Join minus and RJoin minus were rather lower (71 and 49%). Reliability figures were of much the same order: .74-.94 for Combine minus, but .51 and .65 for Join minus and RJoin minus respectively. The lower values most likely resulted from the differences in the number ranges involved in the Join minus and RJoin minus tasks.

As noted earlier, information processing capacity was measured by means of an ESP(S) measure involving number sequence contents on the basis of earlier research (Enumeration Span in Simultaneous Systems, Keranto 1983, 47-52). This was a development of Case's BDS measure (Backward Digit Span, 1972). Reliability figures ranged between .61 and .73. Binomial tests showed an extremely significant ($p < .001$) development of information processing capacity during the first school year. In fact all the first-graders had achieved at least the level of two-unit retention (span=2) by spring. In other words these children were able to hold in mind at least two number words given in advance as the counted up from 1 first to one number then to the other. The numbers were chosen from within the range of numbers the subjects could fluently list.

Findings with regard to question 2: The assessment of the pupils' achievement made by the teachers specifically for this study proved consistent and of high reliability (.90-.95). Stepwise regression analyses ($p < .05$ for both t and F values) indicated that sequence skills and arithmetical strategies accounted for 52-59% of the variance on the various components of mathematics achievement. The best predictors were found to be mental arithmetic skill (PAA) and verbal task solving skill.

Including the information processing capacity variables ESP and SPAN among the predictors increased the predictive power only in the case of verbal task skill (SAN) to a figure of 66%. The figures obtained are in any case high and exceed in some degree the average 50% figures for predictive power anticipated in Bloom's theory of school learning (cf. Bloom 1976, Lahdes 1980, 1982). Predictable, sequence, arithmetical strategies and information processing capacity were not found to be connected to any statistically significant degree with mother tongue achievement. This did not mean, however, that there was no relationship between reading and writing ability and mathematics achievement and counting skills. Indeed, a relatively specific and statistically highly significant relationship was found between mother tongue achievement and the various components of mathematics achievement. This can be seen in more detail in the figure below, which shows the interrelationship of the sum variable CSKILL with the SEQU, ARITME and LANGU variables.

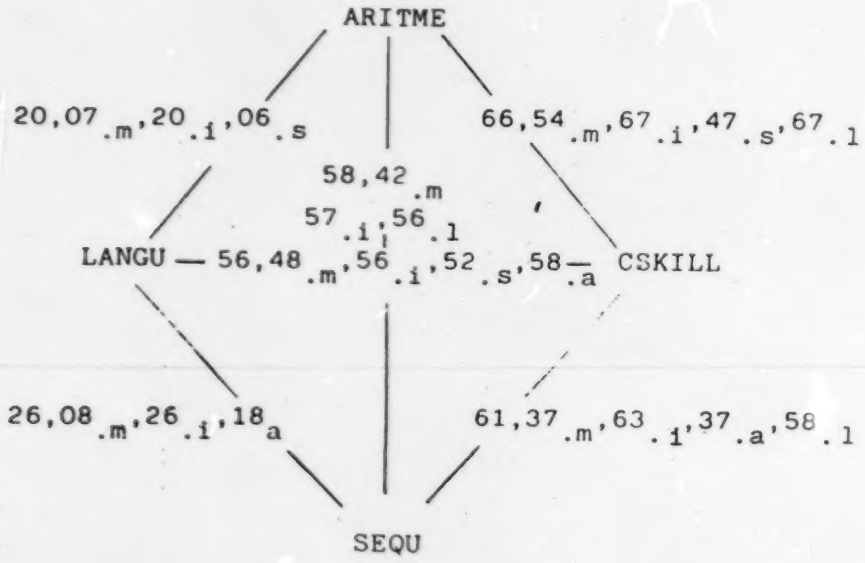

Figure IV 1. A model of the interdependency relations of counting skills (CSKILL), sequence skills (SEQU), arithmetical strategies (ARITME) and mother tongue achievement (LANGU), where .m, .i, .s, .a, .l stand for IPC, age, SEQU, ARITME, LANGU constant (N=35)

In the regression models mother tongue achievement together with sequence skills, arithmetical strategies and information processing capacity predicted 53-67% of the variance on the various components of mathematics achievement. The best predictors were once again mental arithmetic skill and verbal task solving skill. This is logical, since sequence skills, arithmetical strategies and information processing capacity were measured under conditions of oral and mental operation.

Findings with regard to question 3: In determining the dimensions of the attitude measuring instrument factor analyses had been used, which had yielded a theoretical division and a six-factor structure which corresponded well to earlier measurements of attitudes in mathematics learning (overall predictive power 46.5%) (cf. Leino 1977). Similar findings emerged from reliability studies based on both factor analyses and re-test correlations (re-test correlations generally $r \geq .53^{***}$). The variables EMOTIO, DIFF, FEAR, DESIR1-2 and ATTR formed a relatatively reliable whole. With the TRY and NECES items there was the problem of little deviation (nearly all the pupils "wanted to try" and thought that mathematics study was necessary). Comparing the first-graders' answers with those of the second graders tested on the same battery, it was found that the first-graders responses on the KOGN and ESUC variables were more opaque than the second-graders'. An interview would have been necessary in addition to the questioning procedure in order to have ascertained how the children interpreted the questions related to the above-mentioned variables. The same applies to the items measuring social needs (SOC1-4), which represented the most disparate set, and the most problematic as regards content validity, in the whole battery. In relation to reliability, the consistency of individual pupils' responses over two measuring sessions was investigated. It was found that consistency bore a statistically at least near significant relation ($p < .05$) to sequence skills, arithmetical strategies, mathematics achievement and difficulty experienced (DIFF). In other words the weaker the pupils the more changes in response occurred between the two measuring sessions.

T-tests showed that difficulty experienced (DIFF) and attractiveness (ATTR) were best and most widely correlated with sequence skills, arithmetical strategies and mathematics achievement. Variables FEAR and ESUC were also correlated with cognitive variables. The results indicated in the t-tests were also naturally reflected in regression analyses carried out. Attitude variables predicted 14-45% of the variance in sequence skills and arithmetical strategies. The best predictor in the regression models was difficulty experienced (DIFF). A similar finding was made by Leino among upper comprehensive school pupils (Leino 1977). As regards the various components of mathematics achievement attitude variables predicted 31-40% of the variance. Sequence skills, arithmetical strategies and attitude variables taken together predicted 52-67% of the variance on the components of mathematics achievement. When in addition the information processing capacity variables ESP and SPAN were included among the predictors, the predictive power rose as high as 79% in the case of mental arithmetic and verbal task solving skills; and figures were generally high (69-79%), exceeding the 65% average level anticipated by Bloom (Bloom 1976).

Although the results obtained appear for the most part reliable and in accordance with previous experimental findings and theoretical studies, they must still be treated with caution. This is especially the case with the attitude measurements, which in this study were tentative in nature, seeking to discover connections with cognitive processes. Future research could make use of interviews, observation and long-term procedures in the assessment of motivation and attitudes. Only then will it be possible to get a more detailed picture of how motivation in mathematics learning relates to attitudes, the self-view, and cognitive processes.

REFERENCES

Aebli, H. 1963. Über die geistige Entwicklung des Kindes. Stuttgart: Klett

_____. 1967. 'Egocentrism'(Piaget)-not a phase of mental development but a 'substitute solution' for an insoluable task. Pedagogiga Europaea,3, 97-103

_____. 1980. Denken-das Ordnen des Tuns. Band 1. Stuttgart: Klett

Aebli, H., Montada, L. & Schneider, U. 1968. Über den Egozentrismus des Kindes. Stuttgart: Klett

Alderfer, C.P. 1969. A new theory of human needs. Organizational Behavior and Human Performance, 4, 142-175

Atkinson, J.W. 1964. An Introduction to Motivation. Princeton, N.J: Van Nostrand

Bar-Tal, D. 1978. Attributional analysis of achievement -related behavior. Review of educational research, 48, 2, 259-271

Berlyne, D.E. 1960. Conflict, Arousal and Curiosity. N.Y.: McGraw-Hill

Beth, E.V. & Piaget, J. 1966. Mathematical epistemology and psychology. Dordrecht, Holland: Reidel

Bloom, B.S. 1976. Human characteristics and school learning. N.Y.: McGraw-Hill

Brainerd, C.J. 1978. Piaget´s Theory of Intelligence. New Jersey: Prentice-Hall

Bruner, J.S. 1974. The relevance of education. Bungay, Suffolk: Penguin

Carpenter, T.P., Corbitt, M.K., Kepner, H.S., Lindqvist, M.M. & Reys, R.E. 1980. Student affective responses to mathematics: Secondary school results from national assesment. Mathematics Teacher, 73, 7, 531-539

Carpenter, T.P., Hiebert, J. & Moser, J. 1981. The effect of problem structure on first grader´s initial solution procedures for simple addition and subtraction problems. Journal for Research in Mathematics Education 12, 27-39

_____. 1982. Cognitive Development and Children´s Solutions to verbal arithmetic problems. Journal for Research in Mathematics Education 13, 83-98

Case, R. 1972. Validitation of neo-Piagetian mental capacity construct. Journal of Experimental Child Psychology 14, 287-302

Case, R. 1974. Structures and strictures, some functional limitations on the course of cognitive growth. Cognitive Psychology 6, 544-573

_____. 1977. Responsiveness to conservation training as a fuction of subjective uncertainty, M-space and cognitive style. Canadian Journal of Behavioral Science 9, 12-28

_____. 1980. The underlying mechanism of intellectual development. In J.R. Kirby & Biggs, J.B. (Eds.), Cognition Development and Instruction. N.Y.: Academic Press

Case, R. & Globerson, T. 1974. Field independence and central computing space. Child Development 45, 772-778

Case, R. Kurland, M., Daneman, M.& Emanuel, P. 1979. Operational efficiency and growth of M-space. Paper presented at the biennal meeting of the Society for Research in Child Development, San Fransisco

Chung K.H. 1977. Motivational Theories and Practices. Ohio: Grid, Inc.

Collis, K.F. 1975. A study of concrete and formal operations in school mathematics: A Piagetian Viewpoint. Victoria, Australia: Australian Council of Educational Research

Davidov, V.V. & Andronov, V.P. 1979. Psychologian conditions of the origination of ideal actions. English translation: Wingspread Conference, Racine, Wisconsin.

Deci, E.L. 1975. Intrinsic Motivation. N.Y.: Plenum Press

DeCorte, E. & Verschaffel, L. 1981. Children's Solution Processes in Elementary Arithmetic Problems: Analysis and Improvement. Journal of Educational Psychology, 73, 6, 765-779

DeCorte, E., Verschaffel, L. & Verschueren, J. 1982. First grader's solution processes in elementary word problems. Proceedings of the sixth International Conference for the Psychology of Mathematical Education. Antwerp 18-23 July 1982: Universitaire Instelling Antwerpen

Diener, C.J. & Dweck, C.S. 1978. An analysis of learned helplessness: Continuous changes in performance strategy and achievement cognitions following failure. Journal of Personality and Social Psychology, 36, 451-462

Dweck, C.S. & Goetz, T.E. 1978. Attributions and learned helplessness. In J.H. Harvey, W. Ickes & Kidd, R.F. (Eds.), New directions in attribution research. Vol. 2. Hilldale, N.J.: Lawrence Erlbaum

Ekola, J. & Vaherva, T. 1976. Aikuisopetusopas. Helsinki: Tammi

Flavell, J.H. 1963. The development psychology of Jean Piaget. Toronto, London, Melbourne: Van Nostrand

Fuson, K. 1981. The Counting-on Solution Procedure: Analysis and Empirical Results. Wingspread Conference, Wisconsin 1979. To appear in T.Romberg, T. Carpenter & J. Moser (Eds.), Addition and subtraction: A developmental perspective. Expected 1981

Fuson, K. & Hall, J.W. 1982. The Acquisition of Early Number Word Meanings: A conceptual Analysis ans Review In H.P. Ginsburg (Ed.), Children´s Mathematical Thinking. N.Y.: Academic Press

Fuson, K., Richards, J. & Briars, D.J. 1982. The asquisition and elaboration of number word sequence. In C. Brainerd (Ed.), Progress in Cognitive Development. Children´s Logical and Mathematical Cognition, Vol. 1. N.Y.: Springer-Verlag

Galperin, P.J. 1957. An experimental study in the formation of mental actions. Psychologie in Soviet Union, B. Simon (Ed.), London: Routledge and Kegan Paul, 213-225

Gelman, R. & Gallistel, C.R. 1978. The child´s understanding of number. Cambridge, Ma: Harvard University Press

Ginsburg, H. 1977. Children´s Arithmetic: The Learning Process. N.Y.: Van Nostrand

Goldin, G.A. & McClintock, C.E. (Eds.) 1980. Task variables in mathematical problem solving. Ohio State University: ERIC

Guttman, L. 1944. A Basis for scaling qualitative data. American Social Review 9, 139-150

Hebb, D.O. 1949. Organization of Behavior. N.Y.: Wiley

Heinonen, V. 1968. Kansakoulun oppiaineitten arvioinnit. Oppilaitten ja opettajien käsitykset aineitten tärkeydestä, vaikeudesta ja mieluisuudesta 1-2. Moniste. Jyväskylä

Helm, J. 1954. Über den Einfluss affektiver Spannungen auf das Denkhandeln. Zeitschrift für Psychologie, 157, 23-105

Herzberg, F., Mausner, B. & Snyderman, B.B. 1959. The Motivation to Work. N.Y.: Wiley

Hiebert, J. 1981. Cognitive development and learning linear measurement. Journal for Research In Mathematics Education 12, 197-211

Karjalainen, O. 1982. Matematiikan opetuksen affektiiviset tavoitteet ja niiden toteutumisen arvioiminen peruskoulun ala-asteella. Oulun yliopiston kasvatustieteiden tiedekunnan tutkimuksia 10: Oulun yliopiston kasvatustieteiden tiedekunta

Keranto, T. 1978. Esikouluikäisen lapsen lukukäsitteen kehitysasteesta ja laskuvalmiuksista. Hämeenlinna. Tampereen yliopiston Hämeenlinnan OKL:n Julkaisu N:o 1

Keranto, T. 1979. Lapsen lukukäsitteen kehittymisen ja kehittämisen matemaattisdidaktinen näkökulma. Hämeenlinna. Tampereen yliopiston Hämeenlinnan OKL:n Julkaisu N:o 2

_____. 1981. Lukukäsitteen kehittyminen ja kehittäminen: matemaattis-loogiset perusteet ja luvun kognitiivinen rakentuminen. Tampere. Acta Universitatis Tamperensis. Ser. A vol. 125. University of Tampere

_____. 1982. Lapsen matemaattisten ajatteluprosessien ja tiedollisen rakenteen kehitys. Julkaisussa Kognitiiviset prosessit ja matematiikan opetus, P. Kupari (toim.): KTL:n Selosteita ja Tiedotteita 199

_____. 1983. Matemaattiset ajatteluprosessit ja strategiat: yhteydet yksilön tiedolliseen rakentumiseen ja informaation käsittelykapasiteettiin. Hämeenlinna. Tampereen yliopiston OKL:n Julkaisu N:o 8

Konorski, J. 1967. Integrativity Activity of the Brain. Chigago: University of Chigago Press

Kun, A. 1977. Development of the magnitude-covariation and compensation schemate in ability and effort attributions of performance. Child Development, 48, 862-873

Lahdes, E. 1980. Tavoiteoppiminen 1970-luvun jälkipuoliskolla. MLS-projekti: osaraportti 5. Turku. Turun yliopiston kasvatustieteiden laitoksen julkaisuja A:74

_____. 1982. Oppimistulosten varianssiin vaikuttavia tekijöitä. Matemaattisten Aineiden Aikakauskirja 2, 159-162

Lawler, E.E. 1973. Motivation in Work Organizations. Monterey, Calif.: Brooks/Cole

Leino, J. 1977. Matemaattisten kykyjen ja ajatteluprosessien kehittyminen kouluopetuksessa. 1. Matemaattiset kyvyt ja asenteet. Helsinki. Helsingin yliopiston kasvatustieteen laitoksen tutkimuksia N:o 60

_____. 1982. Kognitiivisten prosessien tutkimus matematiikan opetuksessa ulkomailla. Julkaisussa kognitiiviset prosessit ja matematiikan opetus, P. Kupari (toim.): KTL:n Selosteita ja Tiedotteita 199

Madsen, K.B. 1982. Yleinen psykologia: Weilin + Göös; käännös teoksesta Almen Psykologi 1-2 1966, Köpenhamn: Gyldendal

Malinen, P. 1969. The Learning of Elementary Algebra. An Empirical Investigation of the Results of Learning in a Simplified School Learning System. Helsinki. Research Bulletin No. 25. Institute of Education, University of Helsinki

Maslow, A.H. 1954. Motivation and Personality. N.Y.: Harper & Row

McClelland, D.C., Atkinson, J.W., Clark, R. & Lowel, E. 1953. The Achievement Motive. N.Y.: Appleton-Centery

McClelland, D.C. 1975. Toward a theory of motive acquisition. In R.M. Steers & W. Porter (Eds.): Motivation and Work Behavior. N.Y.: McGraw

Myers, M.S. 1964. Who are your motivated workers? Harvard Business Review, 42, 73-88

_____. 1968. Who are your motivated workers? In D.R. Hampton (Ed.): Behavior Concepts in Management. Belmont, Calif., 43-66

Nicholls, J.G. 1975. Causal attributions and other achievement related cognitions: effects of task outcome, atteinment value and sex. Journal of Personality and Social Psychology, 31, 379-389

_____. 1978. The development of the concepts of effort and ability, perception of academic atteinment, and the understanding that difficult tasks require more ability. Child Development, 49, 800-814

Pascual-Leone, J. 1970. A mathematical model for transition rule in Piaget's developmental stages. Acta Psychologica 32, 301-345

Piaget, J. 1952. The Child's Conception of Number. N.Y.: Humanities Press

Puro, J. 1977a. Tukiopetukseen tarvittavan materiaalin kehittäminen II. Peruskoulun ala-asteella kehitettyjen matematiikan tukiopetusmateriaalien käyttökelpoisuuden evaluointi. Jyväskylän yliopisto. KTL:n julkaisuja 269

_____. 1977b. Tukiopetukseen tarvittavan materiaalin kehittäminen III. Peruskoulun ala-asteella kehitettyjen matematiikan tukiopetusmateriaalien käyttökelpoisuuden evaluointi. Jyväskylän yliopisto. KTL:n julkaisuja 270

Ruohotie, P. 1982. Aikuisen opiskelumotivaatio. Hämeenlinna. Tampereen yliopiston Hämeenlinnan OKL:n julkaisu N:o 6

_____. 1982. Motivaatio ja työkäyttäytyminen. Työmotivaatioprojektin yleisjulkaisu. Tampere

Salonen, P., Olkinuora, E. & Lehtinen, E. 1982. Oppimisvaikeuksien interaktiivinen muodostuminen ja kasautuminen. Osaraportti 1: Esitutkimus. Turku. Turun yliopiston kasvatustieteiden laitoksen julkaisuja A:86

Schutz, A. 1970a. Reflections on the problem of relevance. New Haven: Yale University Press

_____. 1970b. On phenomenology and social relations. Chigago: University of Chigago Press

Siegel, S. 1958. Nonparametric statistics for behavioral sciences. N.Y., Toronto, London: McGraw

Steers, R.M.& Porter, L.W. 1975. Motivation and Work Behavior. N.Y.: McGraw-Hill

Thomas, J.W. 1980. Agency and achievement: self-management and self-regard. Review of educational research, 50, 213-240

Weiner, B. 1972. Theories of motivation: from mechanism to cognition. Chigago: Markham

_____ . 1974. (Ed.) Achievement motivation and attribution theory. Morristown, N.J.: General Learning Press

_____. 1979. A theory of motivation for some classroom experiences. Journal of Educational Psychology, 71, 3-25

Vroom, V.H. 1964. Work and Motivation. N.Y.: Wiley

Vygotsky, L.V. 1962. Thought and Language. The Massachusetts Institute of Technology, Cambridge, Massachusetts: M.I.T. Press